A woman with dark hair tied back, wearing a blue and green plaid dress and a gold necklace with a circular pendant, is smiling while cooking. She is holding a knife and appears to be stirring or slicing something in a pan. The background is a blurred kitchen with shelves and a window. A large green and yellow curved graphic element is overlaid on the bottom left of the image.

# **CHAPTER 2** ACCESS TO CLEAN FUELS AND TECHNOLOGIES FOR COOKING



# Main Messages

- **Global trend.** In 2021, 71 percent (67-75) of the global population had access to clean cooking fuels and technologies, an increase of 14 points since 2010.<sup>34</sup> Despite the progress, some 2.3 billion people (2.0-2.6) still use polluting fuels and technologies for most of their cooking.
- **Target for 2030.** Efforts to accelerate the achievement of universal access to clean cooking by 2030 are urgently needed. Current trends suggest that only 77 (73-80) percent of the world's people are expected to have access to clean cooking fuels and technologies by 2030, leaving some 1.9 billion continuing to rely on traditional and inefficient stoves paired with solid fuels (wood, charcoal, coal, crop waste) and kerosene for cooking. Looking beyond 2030 and accounting for population growth, the current business-as-usual trajectory shows that, by 2050, 2.3 billion people in 91 low- and middle-income countries will still lack access to clean cooking. Among the 91 are 45 out of the 47 countries of Sub-Saharan Africa. If current trends continue, around 6 out of 10 people without clean cooking access will reside in Sub-Saharan Africa in 2030, with little or no improvement expected by 2050.
- **Regional highlights.** The access deficit has decreased consistently in Eastern Asia and South-eastern Asia since 2000, and in Central Asia and Southern Asia since 2010. However, in Sub-Saharan Africa, there has been a clear upward trend in the deficit, as access to clean cooking has failed to keep pace with growing populations. There, it has more than doubled since 1990 and has increased by 60 percent since 2000, reaching a total of 0.9 billion people (0.9-1.0) in 2021. Without new policies or urgent interventions, the access deficit in Sub-Saharan Africa is on course to reach 1.1 billion people in 2030, with no signs of slowing thereafter.
- **Urban-rural divide.** Urban areas continue to have greater access to clean cooking than rural areas, but the divide is narrowing over time. Over the last 10 years, access accelerated in rural areas and decelerated in urban areas. The percentage of people with access in urban areas rose only slightly from 82 percent (78-84) in 2010 to 86 percent (83-89) in 2021. Meanwhile, over the same period, the percentage in rural areas rose from 31 percent (27-35) to 51 percent (46-56), five times the improvement seen in urban areas over the same period. If the urban trends continue to decelerate, the percentage of the population with access to clean cooking in urban areas is on course to stall and possibly to begin dropping as soon as 2025.
- **The 20 countries with the largest access deficits.** The 20 countries with the largest access deficits accounted for 78 percent of the global population lacking access to clean cooking, including 10 countries in Sub-Saharan Africa, where more than 600 million people still lacked access to clean cooking fuels and technologies in 2021. In 16 of the 20 countries, less than half of the population had access to clean cooking fuels and technologies. Moreover, in seven (all in Sub-Saharan Africa), less than 10 percent of the population had access.

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<sup>34</sup> Throughout the chapter, parenthetical figures appearing after estimates are 95 percent uncertainty intervals, as defined in the methodology section at the end of the chapter. Clean fuels and technologies include stoves powered by electricity, liquefied petroleum gas (LPG), natural gas, biogas, solar, and alcohol. Clean fuels and technologies are as defined by the normative technical recommendations in the WHO Guidelines for Indoor Air Quality: Household Fuel Combustion (WHO 2014).

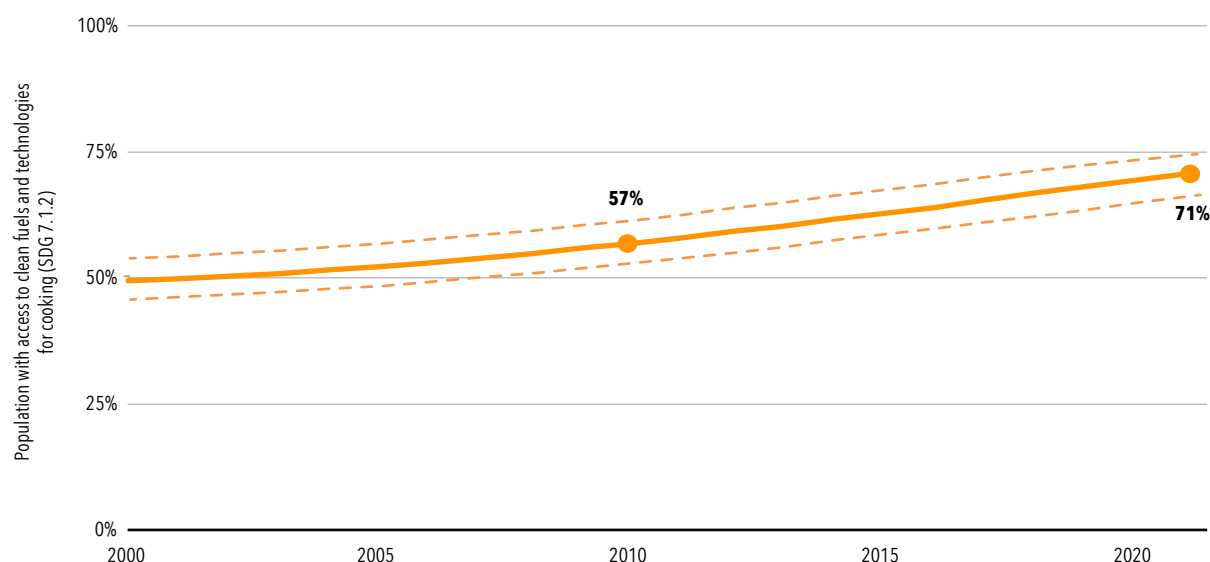
- **The 20 countries with the lowest access rates.** Almost all of the 20 countries with the lowest rates of access to clean cooking, with the exception of Rwanda, have shown little or no progress in increasing their access rates between 2017 and 2021 (with an increase of less than 0.4 percentage points). Nineteen of these countries are in Africa and are among the least-developed countries, with Haiti the only non-African country among them.
- **Global and regional fuel trends.** In low- and middle-income countries in 2021, gaseous fuels (liquefied petroleum gas [LPG], natural gas, biogas) were used by 55 percent (49–60) of people (3.6 billion) as their main energy source for cooking. Unprocessed biomass (wood, crop waste, dung) was the main fuel of 29 percent (24–34) of people (1.9 billion); electricity, of 10 percent (7–14) of people (660 million); and charcoal, of 4 percent (3–4) of people (240 million). Only 1 percent of people still used coal and kerosene as their main fuels in 2021.
- **Clean cooking as a cost-effective measure to tackle climate change.** Clean cooking can and should be an integral part of strategies for achieving the targets specified in Nationally Determined Contributions (NDCs) under the Paris Agreement on climate change and advancing toward the goal of net zero emissions by 2050 and achieving Sustainable Development Goals 7, 9, and 13. New evidence on the climate, health, and social benefits of transitioning to clean cooking strengthens the argument for universal clean cooking as a way to accelerate the energy transition.
- **Energy compacts driving policy action and commitments for clean cooking.** Energy compacts that lead to national clean cooking strategies and commitments are an important vehicle for countries to accelerate the transition to clean cooking. Numerous state and non-state actors, such as companies, regional and local governments, and nongovernmental organizations have joined in the commitment to accelerate access to clean cooking. If realized, national targets to accelerate access to clean cooking, as spelled out in NDCs and energy compacts, have the potential to improve human health, livelihoods, the climate, and the natural environment at large. Promoting the use of a range of cleaner cooking fuel options such as electricity, LPG, ethanol, and biogas should thus be upheld as an important implementable action for countries to use to advance development outcomes, preserve nature, and mitigate and adapt to the effects of climate change.

# Are We on Track?

**The world is not on track to achieve universal access to clean cooking by 2030.** In 2021, only 71 percent (67–75) of the global population had access to clean cooking fuels and technologies, the latter comprising stoves powered by electricity, LPG, natural gas, biogas, solar energy, and alcohol. However, this leaves 2.3 billion people (2.0–2.6) still relying primarily on polluting fuels and technologies, such as simple stoves paired with charcoal, coal, crop waste, dung, kerosene, or wood.<sup>35</sup>

There has been some progress in the global access rate over the past two decades, as seen in figure 2.1. Yet if current trends continue, only an estimated 77 percent (73–80) of the global population will have access to clean cooking fuels and technologies by 2030, falling far short of the 2030 target of universal access and leaving 1.9 billion people to suffer the damaging effects of polluting cooking fuels and technologies on human health, livelihoods and the environment.

**Figure 2.1 • Percentage of the global population with access to clean cooking fuels and technologies, 2000–21**



Source: WHO 2023.

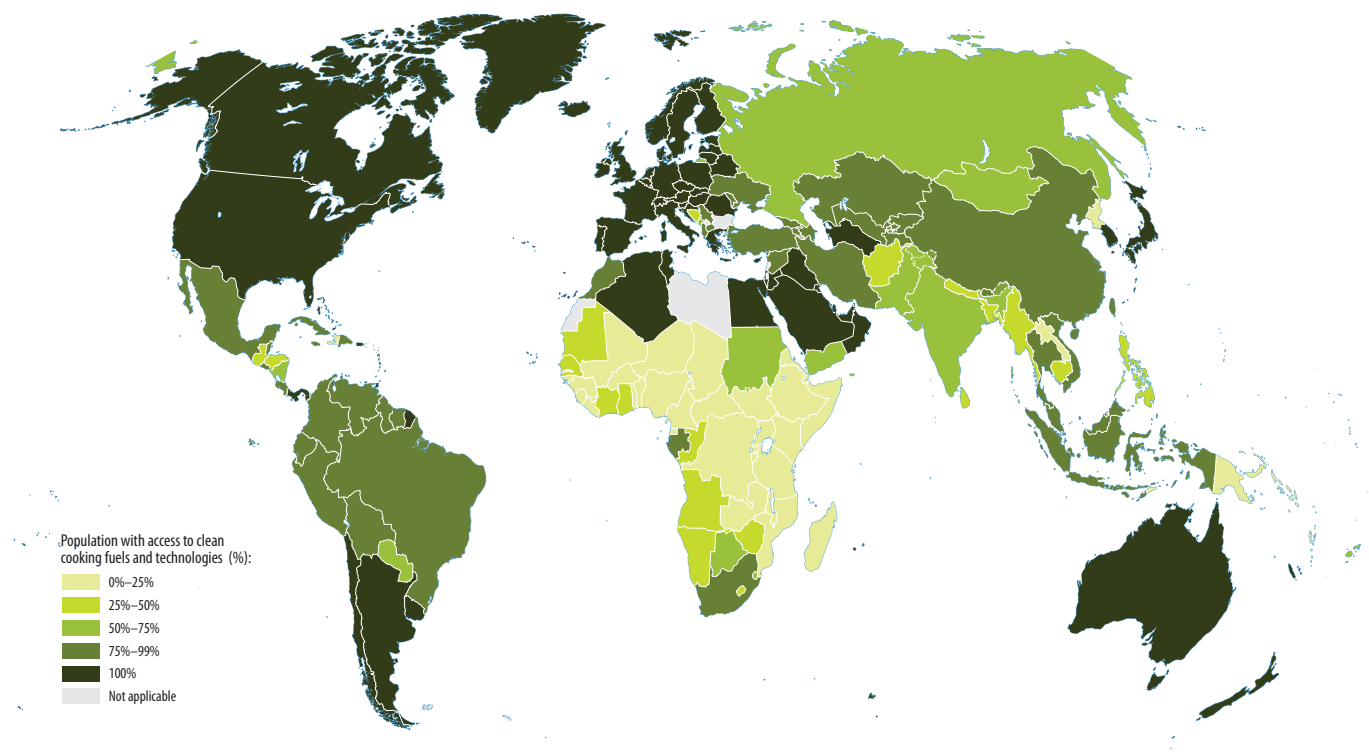
Note: Dashed lines are 95% uncertainty intervals.

Globally, the number of people without access to clean cooking continues to decrease each year. However, large regional variability exists (figures 2.2 and 2.3). In fact, the number of people without access in Sub-Saharan Africa is growing at a rate of almost 20 million people per year as gains in the share of people with access fail to keep pace with population growth, to the detriment of the almost 1 billion people already suffering the negative effects of polluting cooking in the region. The growing access deficit in Sub-Saharan Africa, if not reversed, could dampen or undermine current increasing trends in global access.

35 Because of the data-driven nature of the analysis and limitations in the data, this chapter examines cooking fuel rather than cookstove and fuel combinations. The methodology section at the end of the chapter provides additional details. Population estimates are from 2021. Population data from the 2018 revision of World Urbanization Prospects were used to derive the population-weighted regional and global aggregates. Low- and middle-income countries without data were excluded from all aggregate calculations; high-income countries were excluded from aggregate calculation for specific fuels.



**Figure 2.2 • Share of population with access to clean cooking fuels and technologies, 2021 (percent)**



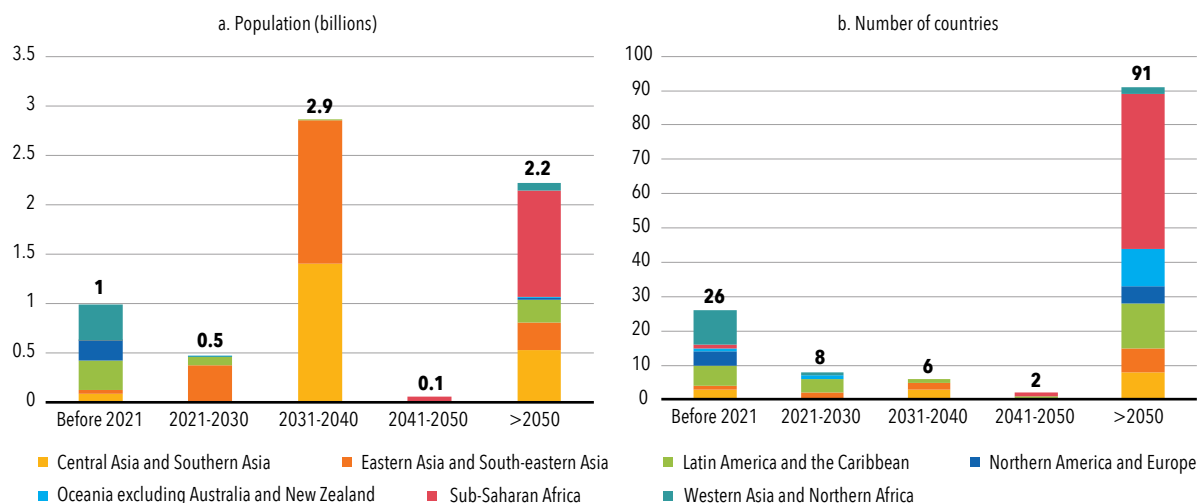
Source: WHO 2023.

*Disclaimer:* This map was produced by the Geospatial Operations Support Team of the World Bank based on the Cartography Unit of the World Bank. The boundaries, colors, denominations, and other information shown do not imply any judgment on the part of the custodian agencies concerning the legal status of or sovereignty over any territory or the endorsement or acceptance of such boundaries.

Without much stronger efforts, the great majority of low- and middle-income countries will miss the 2030 universal access target and beyond (figure 2.3). Eight countries with a total population of 500 million in 2021 are expected to achieve universal access<sup>36</sup> in the period 2021–30. A further six countries with a combined population of 2.9 billion are on track to transition to universal clean cooking between 2031 and 2040. However, just two countries are on track to cross this threshold between 2041 and 2050. Most alarmingly, 80 countries with a total population of 2 billion are not expected to reach even 90 percent clean cooking coverage by 2050.

36 Due to the inherent uncertainty in input survey data and modelled estimates, for SDG 7.1.2 monitoring, countries are assumed to have universal access if modelled estimates indicate that 95 percent or more primarily rely on clean fuels and technology for cooking.

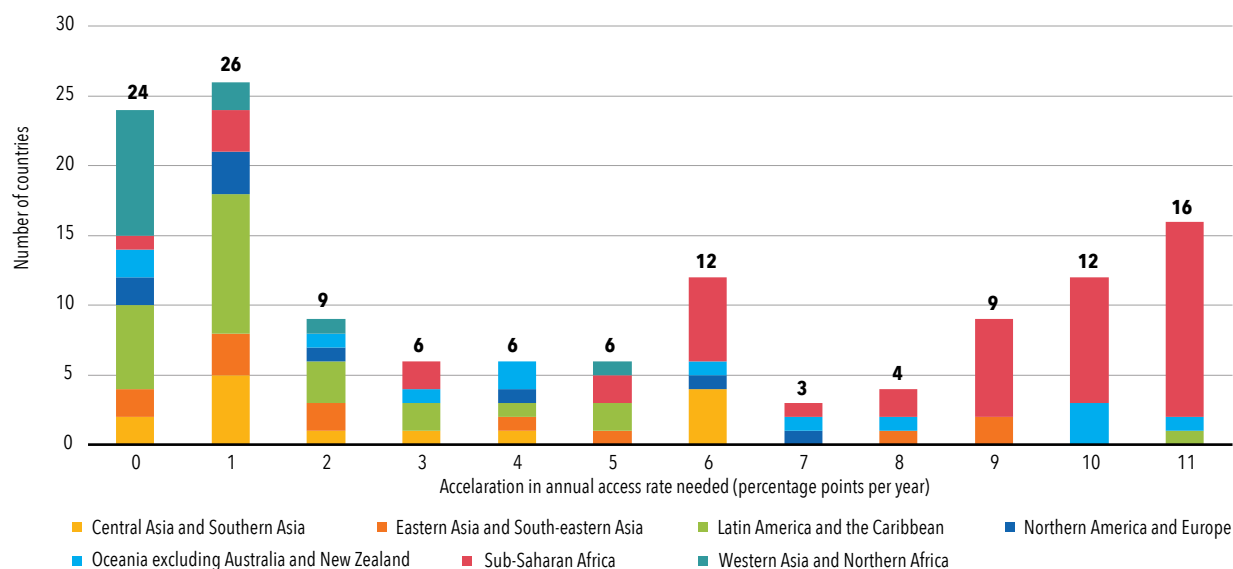
**Figure 2.3 • Total population and number of LMICs expected to achieve universal access to clean cooking, based on current trends by region**



Source: WHO 2023.

An acceleration of progress is therefore urgently needed if the world is to achieve universal access by 2030. In 41 countries, predominantly in Sub-Saharan Africa, additional increases of 8–11 percentage points per year above the current trends are needed to reach 100 percent access from 2021 to 2030 (figure 2.4). Furthermore, without an additional 1–3 percentage point increase in access per year, 82 countries will not reach universal access to clean cooking by 2050, with 45 of these countries in Sub-Saharan Africa.

**Figure 2.4 • Additional annual rate of increase in access to clean cooking from 2021 to 2030 in access-deficit countries needed to universal clean cooking by 2030**



Source: WHO 2023.

Note: Additional increases are rounded to the nearest percentage point.

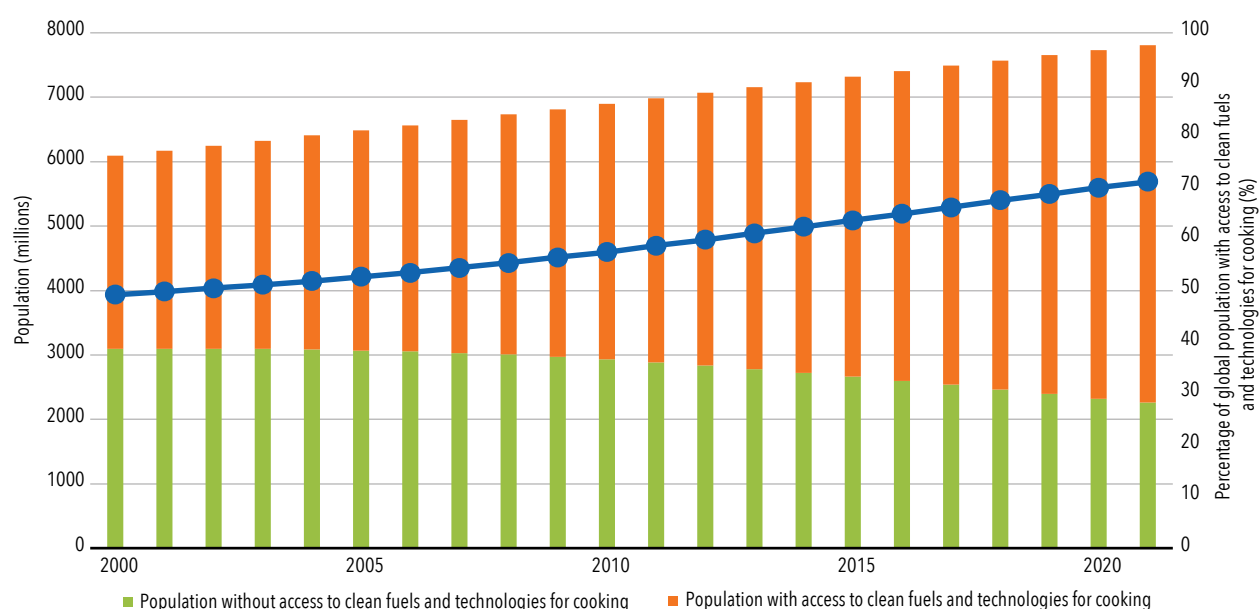
With current trends, the number of people with access to clean cooking will increase by 510 million people from 2021 to 2025. This demonstrates the considerable and urgent need to scale up action to ensure an additional 1 billion people obtain access to clean cooking solutions by 2025, as pledged by the Global Roadmap for Accelerated SDG7 Action in Support of the 2030 Agenda for Sustainable Development and in effort to achieve the Paris Agreement on Climate Change.

# Looking Beyond the Main Indicators

## ACCESS AND POPULATION

The global rate of access to clean fuels and technologies for cooking reached 71 percent (67–75) in 2021. Figure 2.5 shows a gradual increase in the access rate over the past two decades, with a total increase of around 22 percentage points since 2000.

**Figure 2.5 • Change in the absolute number of people (left axis, bars) and percentage of the global population (right axis, line) with access to clean cooking, 2000–21**

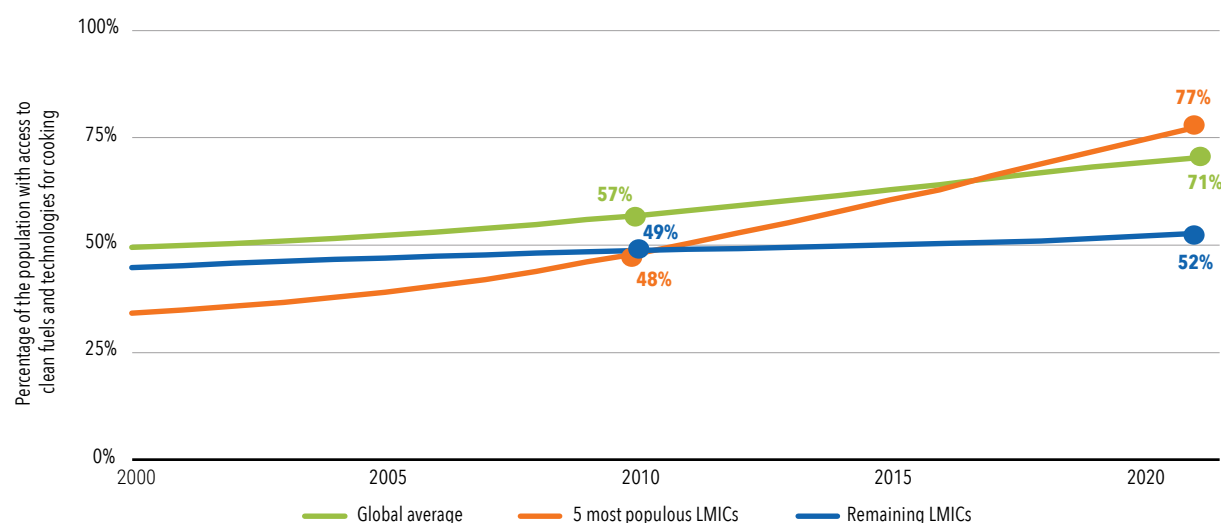


Source: WHO 2023.

Improvement in the global access rate has been predominantly driven by progress in the most populous low- and middle-income countries. Figure 2.6 illustrates a clear contrast between the progress in China, India, Indonesia, Brazil, and Pakistan, where the combined access rate rose from 49 percent in 2010 to 77 percent in 2021, and the minimal progress in other LMIC (48 percent in 2010 to 52 percent in 2021). This is a stark reminder that good progress in the largest countries may obscure the lack of progress in a great many smaller countries.



**Figure 2.6 • Percentage of population with access to clean cooking globally, in five most populous LMICs, and all other LMICs, 2000-21**



Source: WHO 2023.

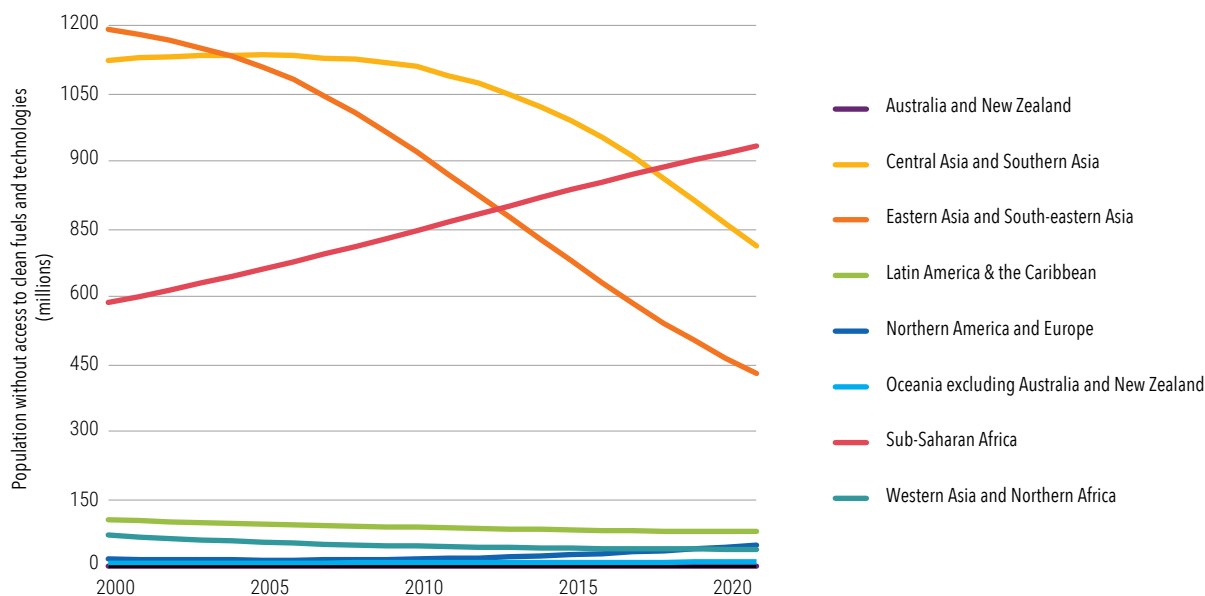
LMICs = low- and middle-income countries.

## THE ACCESS DEFICIT

On a global scale, the number of people with access to clean cooking has risen consistently over the last two decades (figure 2.5). However, the total number of people lacking access to clean cooking—a measure of the number exposed to the damaging health and socioeconomic effects of polluting fuels and technologies, referred to here as the “access deficit”—began to fall substantially only after 2010, dropping from its historic level of around 3 billion people to 2.3 billion people (2.0–2.6) in 2021.

Reductions in the total number of people lacking access have been slowed by both population growth and an uneven geographic distribution of progress. Figure 2.7 shows how the deficit has decreased consistently in Eastern Asia and South-eastern Asia since 2000, and in Central Asia and Southern Asia since 2010. Alarmingly, however, the access deficit in Sub-Saharan Africa has more than doubled since 1990, as population growth has outpaced limited progress in the percentage of the population with access to clean cooking. The deficit has grown 60 percent since 2000, reaching a total of 0.9 billion people (0.9–1.0) in 2021. Without new policies or interventions, the deficit is on track to reach 1.1 billion people by 2030, with no sign of abatement thereafter.

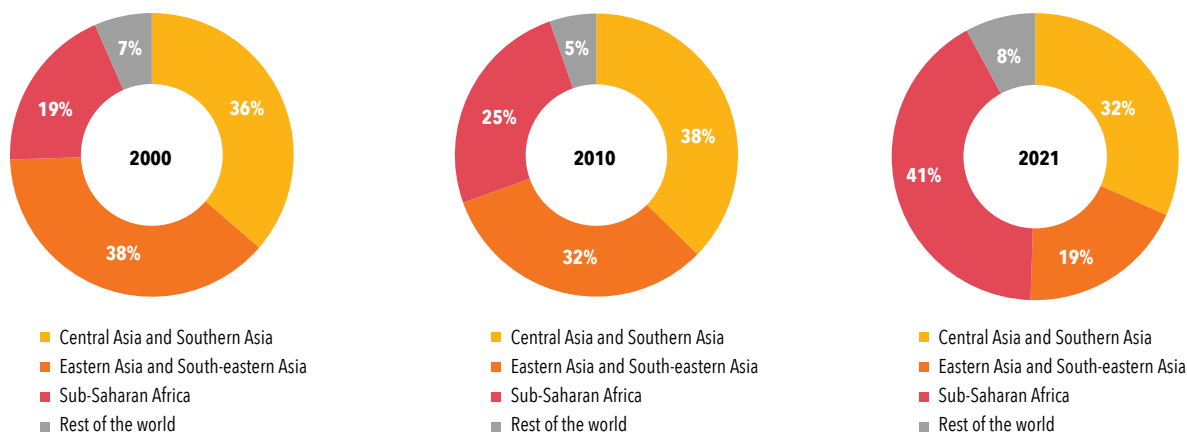
**Figure 2.7 • Number of people without access to clean fuels and technologies, by region, 2000–21**



Source: WHO 2023; Stoner and others 2021.

Figure 2.8 illustrates the changing regional composition of the global population lacking access to clean fuels for cooking between 2010 and 2021. In 2000, four in ten people lacking access to clean cooking lived in Central Asia and Southern Asia; four in ten in Eastern Asia and South-eastern Asian; and two in ten in Sub-Saharan Africa. By 2021, four in ten people without access lived in Sub-Saharan Africa as a result of decreases in the access deficit in the two Asian regions and a stark increase in the deficit in Sub-Saharan Africa. If current trends continue, almost six in ten people without access will reside in Sub-Saharan Africa by 2030.

**Figure 2.8 • Proportion of the total global access-deficit in the three largest access-deficit regions and the rest of the world, 2000, 2010 and 2021**



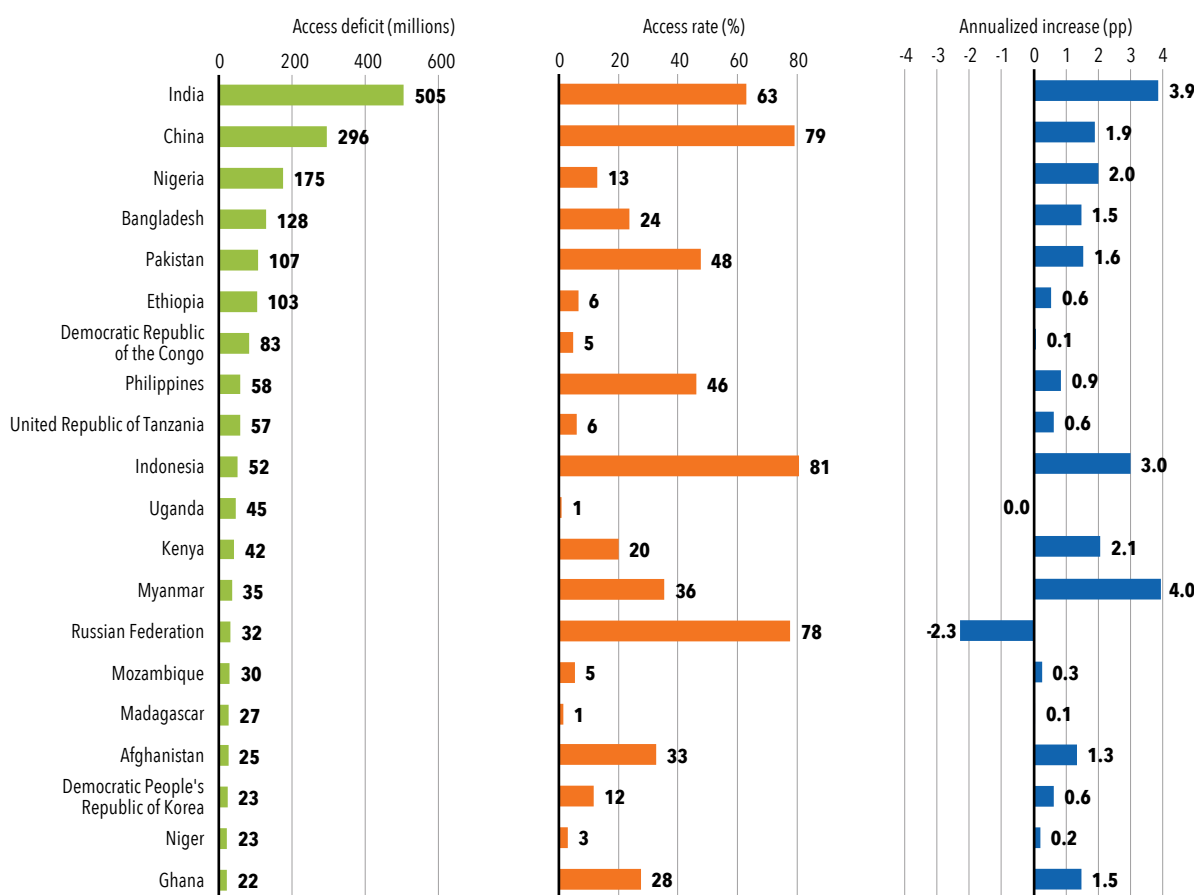
Source: WHO 2023; Stoner and others 2021.

## ANALYSIS OF THE TOP 20 ACCESS-DEFICIT COUNTRIES

More than three-quarters (78 percent) of the world's people lacking access to clean cooking are found in the 20 countries shown in figure 2.9. India alone accounts for the largest share of the access deficit, with 505 million people lacking access, followed by China at 296 million.

In seven of the twenty countries, less than 10 percent of the population has access to clean fuels and technologies; the seven are Democratic Republic of the Congo, Ethiopia, Madagascar, Mozambique, Niger, Uganda, and the United Republic of Tanzania. Sixteen of the twenty countries have access rates below 50 percent.

**Figure 2.9 • The 20 countries with the largest access deficit by absolute population (green) , 2017 - 2021 average**



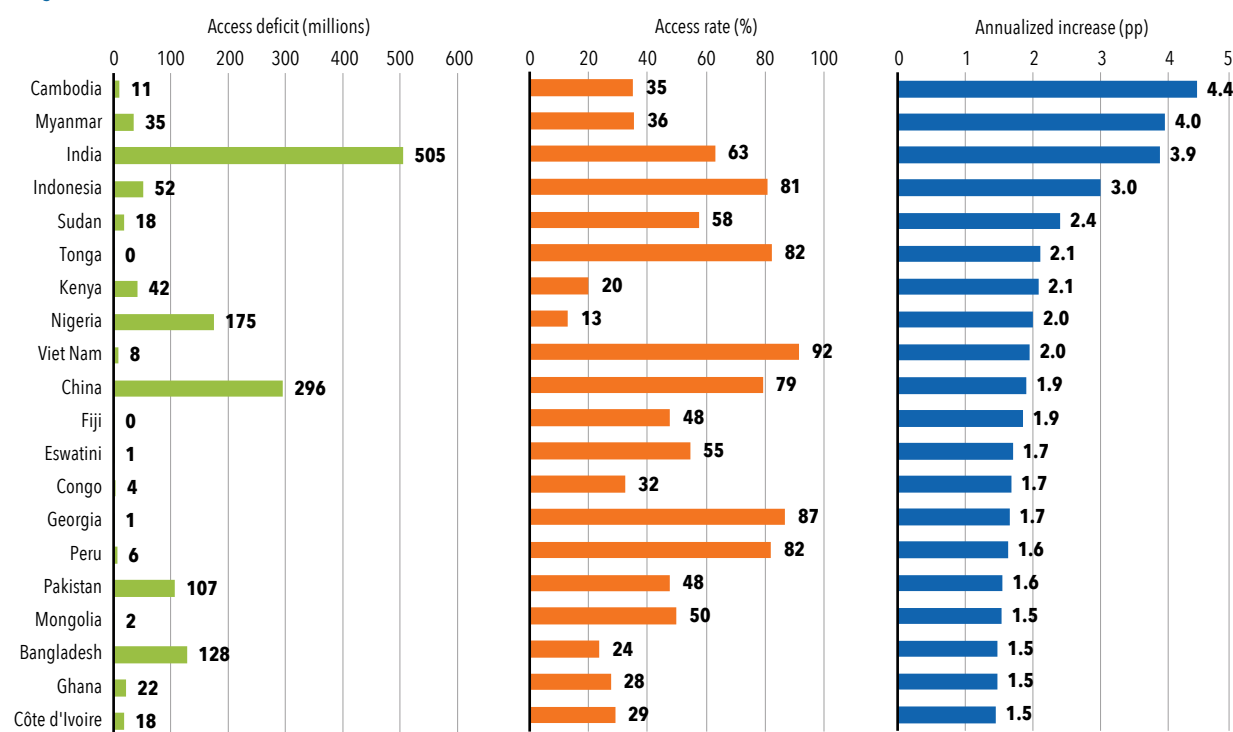
Source: WHO 2023..

pp = percentage point.

Although India has the largest population without access to clean cooking, the rate of access in the country increased by 3.9 percentage points per year on average between 2017 and 2021 (figure 2.10). Cambodia had the highest rate of increase, at 4.4 percentage points per year, followed by Myanmar at 4 percentage points. Other countries with annual gains of at least 2 percentage points were India, Indonesia, Sudan, Tonga, Kenya, Nigeria, and Viet Nam.



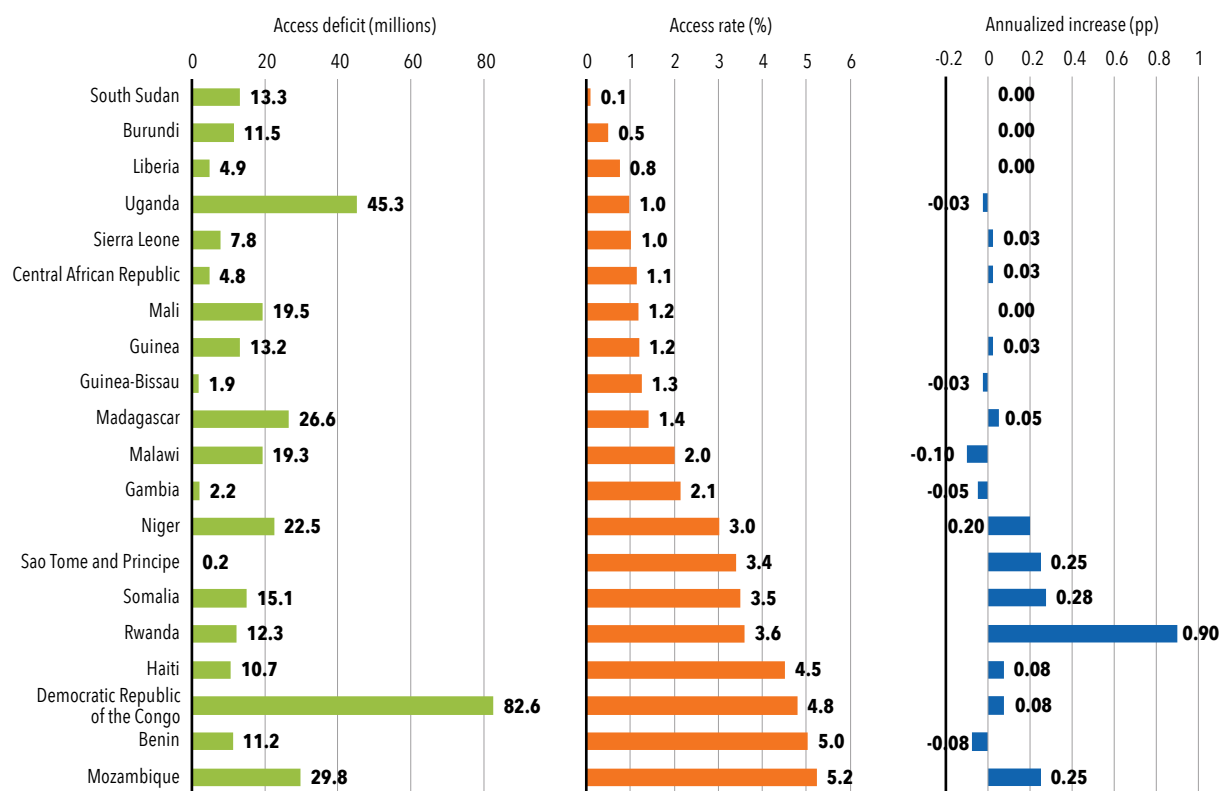
**Figure 2.10 • The 20 countries with the largest annual increases in the percentage of people with access to clean fuels and technologies (blue), 2017–21 average**



Source: WHO 2023.  
pp = percentage point.

Nearly all of the 20 countries with the lowest access rates showed little or no sign of improvement (figure 2.11). In almost all of these countries, the average annual increase in access between 2017 and 2021 was below 0.4 percentage points per year; access decreased in some countries. Only Rwanda had a slightly higher average increase of 0.9 percentage points per year. All of these countries except Haiti are in Sub-Saharan Africa. These countries also have some of the least financing dedicated to clean cooking (SEforALL 2021).

**Figure 2.11 • The 20 countries with the lowest rates of access to clean fuels and technologies (orange), 2017-2021 average**

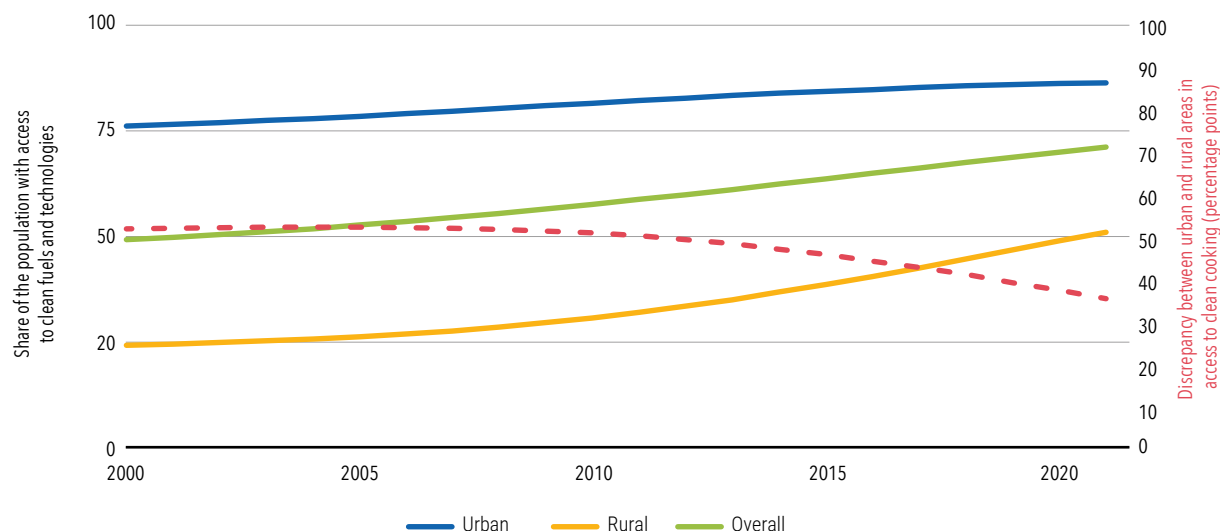


Source: WHO 2023.  
pp = percentage point.

## URBAN-RURAL DIVIDE

Urban areas have greater access to clean cooking than rural areas, but the gap is narrowing. The percentage of people with access in urban areas rose only slightly in the past decade—from 82 percent (78–84) in 2010 to 86 percent (83–89) in 2021 (figure 2.12). Over the same period, the percentage in rural areas rose from 31 percent (27–35) to 51 percent (46–56). Between 2000 and 2010, by contrast, the difference in access to clean cooking between urban and rural areas stood steadily at around 50 percentage points. By 2021 the gap had since fallen to 35 percentage points (29–41) and is expected to narrow further still to 23 percentage points in 2030 if current trends continue.

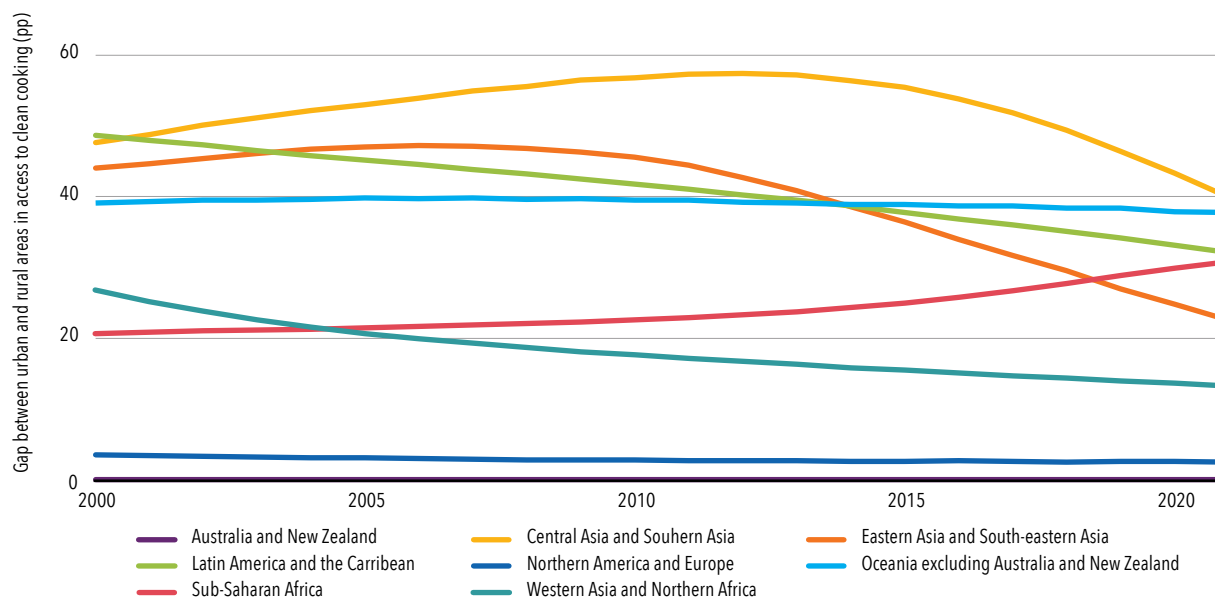
**Figure 2.12 • Percentage of people with access to clean cooking in urban areas, rural areas, and overall (solid lines), and discrepancy in access between urban and rural areas (dashed line)**



Source: WHO 2023.

The discrepancy in access between urban and rural areas is highest in Central Asia and Southern Asia (figure 2.13), at 40 percentage points (29–52). The gap is narrowing in all regions except Sub-Saharan Africa, where it is increasing sharply.

**Figure 2.13 • Discrepancy in access between urban and rural areas, by region**



Source: WHO 2023.

pp = percentage point.



From 2010 to 2021, access to clean cooking improved at an annual rate of 2.0 (1.3–2.6) percentage points per year in rural areas and 0.5 percentage points per year (0.0–0.9) in urban areas. The regions with the fastest progress in rural areas were Central Asia and Southern Asia, with an annual increase of 3.3 (2.0–4.3) percentage points since 2010, and Eastern and South-eastern Asia, 3.4 (1.4–4.9) percentage points. In Sub-Saharan Africa, the access rate in rural areas was stagnant, with annualized increases of just 0.1 percentage point over this period. Globally, progress in rural areas has accelerated sharply in rural areas since 2000, though there has been a slight deceleration since 2017. In urban areas, progress has steadily decelerated for more than 10 years. If these trends continue, the rate of access to clean cooking in urban areas is on course to stall and possibly begin declining as early as 2025.

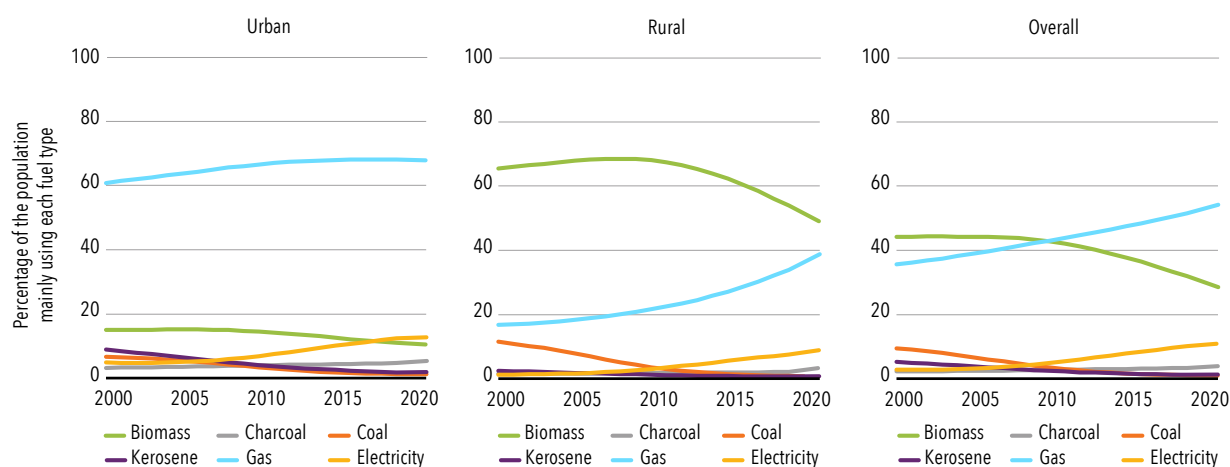
## CHANGES IN THE FUEL MIX

Taking a deeper look at the specific fuels and technologies being used in 2021, gaseous fuels (LPG, natural gas, biogas<sup>37</sup>) were the main energy source for cooking of 55 percent (49–60) of people (3.6 billion) (figures 2.14 and 2.15); electricity was the main fuel for 10 percent (7–14) of people (660 million). Unprocessed biomass (wood, crop waste, dung), a polluting alternative, was the main fuel for 29 percent (24–34) of people (1.9 billion); charcoal of 4 percent (3–4) (240 million). Only 1 percent of people used coal as their main fuel; a similar percentage used kerosene.

Unprocessed biomass, once the most commonly used fuel in low- and middle-income countries, was overtaken by gas around 2010 owing to the rapid growth of LPG programs in India, Indonesia, and Peru, among other countries. However, in rural areas, biomass was still the principal cooking fuel of 49 percent (44–54) of people (1.5 billion) in 2021, more than any other type of fuel. Use of unprocessed biomass may be decreasing in both urban and rural areas, but primary reliance on charcoal persists and is increasing in some areas, particularly urban areas of Sub-Saharan Africa, where it was used by 30 percent (27–34) of people (140 million) in 2021.

The percentage of people who use gas as their primary fuel is rising more quickly than those who use electricity in rural areas. Whereas the use of electricity is rising more quickly in urban areas. Among low- and middle-income countries, the use of electricity is highest in Eastern Asia and South-eastern, at 24 percent (15–34) of people or about 500 million people living in low- and middle-income countries of these regions in 2021.

**Figure 2.14 • Percentage of people using each cooking fuel type in low- and middle- income countries, for urban areas, rural areas and overall**

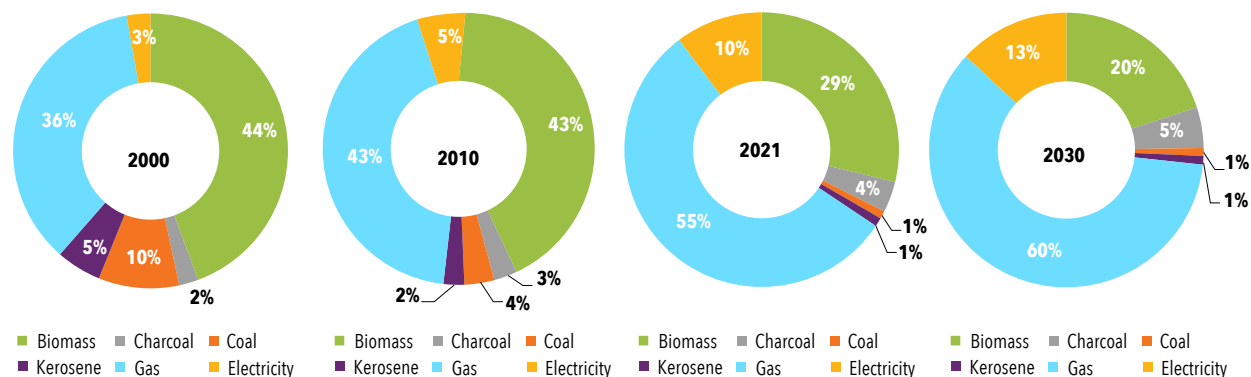


Source: WHO 2023.

37 Gaseous fuels (or gas) refers to LPG, natural gas, and biogas together, as many input surveys do not differentiate among the three.

Progress in the percentage of people using clean fuels and technologies for cooking has been accompanied by steep declines in the use of unprocessed coal and kerosene. In 2000, coal was mainly used by 10 percent (6-15) of the population (480 million people) in low- and middle-income countries, the overwhelming majority of whom (450 million) lived in Eastern Asia and South-eastern Asia (24 percent [13-38] of the population in this region). In 2000, kerosene was the main cooking fuel of 5 percent (4-7) of the population in low- and middle-income countries (260 million people), including 18 percent (14-22) of those (48 million) in urban areas of Sub-Saharan Africa and 26 percent (15-39) of those in urban areas of Oceania (excluding Australia and New Zealand). In 2021, the use of kerosene or coal as the main fuel for cooking fell to a combined 2 percent of the population in LMICs.

**Figure 2.15 • Comparison of the percentage of people in LMICs using various fuel types in 2000, 2010 and 2021, with projection for 2030**



Source: WHO 2023.

If current trends continue through to 2030, 60 percent of the population in low- and middle-income countries will mainly use gas; 20 percent unprocessed biomass; 12 percent electricity; 5 percent charcoal; 1 percent kerosene; and 1 percent coal. Gaseous fuels, rather than electricity, will account for most of the growth in the share of the population using clean fuels and technologies predominantly.

Fuel stacking (the simultaneous use of several different fuels and stoves) remains extremely common, but the statistics presented here address only the primary cooking fuel, as survey data typically do not account for other fuels used. The number of people relying exclusively on clean fuels is therefore likely to be much smaller than implied by the numbers cited here. Analysis of all cooking fuels used will be possible with greater adoption of survey questions that capture all fuels and technologies used for cooking (World Bank and WHO 2021).

# Policy Insights

Clean cooking is a key element of sustainable development. Scaling it up saves lives, enhances well-being, and protects the climate, but the world is falling behind in attaining the goal of universal access by 2030. Putting the world back on track toward the goal will require an immediate boost in cross-sectoral collaboration and action. The need is urgent for public, private and nongovernmental actors working in health, energy, environment, finance, and social development to come together to elevate political commitment, dramatically increase investment, and step up cross-sectoral coordination. Advancing the transition to clean fuels and technologies is a guaranteed win-win for human health and well-being and protection of the natural environment and the climate. The greater the investment, the quicker the win.

## CLEAN COOKING: AN ESSENTIAL INGREDIENT FOR IMPROVING LIVES AND GENDER EQUITY

Ensuring healthy lives and promoting well-being for all at all ages (SDG 3) require not only actions that address well-known health risk factors such as active and passive tobacco smoking, harmful use of alcohol, unhealthy diet, and insufficient physical activity, but also other actions that protect people from breathing polluted air in their homes.

In 2021, almost one-third (29 percent) of the world's population still lacked access to clean fuels and technologies for cooking. Such energy poverty puts the health and well-being of the poorest populations at risk, while also contributing to climate change, perpetuating gender inequity, and compromising efforts for sustainable development.

The health consequences that result from household air pollution are stark and tragic. The use of inefficient stoves paired with solid fuels and kerosene releases high-levels of air pollution that puts household members, particularly women and children, at greater risk of acute and chronic disease. The latest estimates for 2019 from the World Health Organization show that 3.2 million deaths are attributable to household air pollution each year (WHO 2022). About 240 000 deaths in children under the age of five are due to household air pollution (WHO 2021a). More than three-quarters of the deaths attributed to household air pollution are from noncommunicable diseases like ischemic heart disease, stroke, chronic obstructive pulmonary disease, and lung cancer. Failure to reach the target of universal access to clean cooking fuels and technologies will continue to claim millions of lives each year.

The lack of access to clean fuels and modern energy systems for cooking impacts beyond health, preventing many from living life to the fullest. The drudgery posed by reliance on inefficient stoves and fuels often falls disproportionately on women and children, particularly girls. The time loss from collecting fuels and preparing meals using inefficient methods keeps them from other social and productive activities like schooling or income-generation, thus hindering the quest for quality education and gender equality for all (SDGs 4 and 5). Such tasks also put them at risk of violence.

Given that current estimates consider only the impact of fuels used for cooking (WHO 2016), the global health toll of energy poverty in households would likely be even greater if the use of polluting fuels and devices for lighting and heating were also accounted for. Household energy is an important source of ambient (outdoor) air pollution (SDG 11); in some communities it accounts for over half of ambient air pollution (WHO 2016; WHO 2021).



## EMPOWERING WOMEN ENTREPRENEURS IN CLEAN COOKING: ADVANCING BOTH GENDER EQUITY AND ACCESS TO ENERGY

Empowerment and mentorship programs for women entrepreneurs in the clean cooking value chain have proven effective in promoting a more gender-inclusive workforce. Better representation of women in energy sector policy- and decision-making and more active participation of women entrepreneurs in the clean cooking value chain are important ways to advance gender equity and ensure that efforts to expand access meet the needs of cookstove users (Clean Cooking Alliance 2023). For example, in Nepal, where a transition to e-cooking is underway, a lack of availability of after-sales services was becoming a challenge. To address this gap, the Women's Network for Energy and Environment, with the support of the Gender and Energy Innovation Facility, trained women who owned or worked in electrical appliance stores to provide maintenance and repair services for electric stoves. Such innovation promotes clean cooking, and women's participation in the energy value chain, all the while providing women with additional income and customers a place to go for appliance repair (ENERGIA 2022).

## THE URGENT NEED FOR CLEAN COOKING TO COMBAT CLIMATE CHANGE

The lack of widespread access to clean fuels and technologies for cooking has been shown not only to imperil health and exacerbate gender inequality, but also to damage the globe's fragile climate through deforestation from unsustainable wood harvesting and burning of polluting fuels in inefficient stoves. These practices generate greenhouse gases and climate pollutants such as black carbon, which is the second-largest contributor to climate change after carbon dioxide (CO<sub>2</sub>) (Bond and others 2013).<sup>38</sup> Household fuel combustion produces about half of the global emissions of black carbon (WHO 2016; Floess and others 2023) and is responsible for many of the climate change impacts seen today—disrupting regional environmental systems (such as the Arctic and the high mountain glaciers of the Himalayas) that are critical to human welfare, wildlife habitats, and surrounding ecosystems.

## CLEAN ENERGY FOR COOKING: A PATHWAY TO CLIMATE AND HEALTH CO-BENEFITS

Expanding access to clean energy for cooking can immediately begin to mitigate these damages, offering an unparalleled opportunity for climate and health co-benefits. Black carbon's short lifespan in the atmosphere (on the order of days to weeks) means that reducing its emissions can slow warming immediately. Replacing biomass with electricity and LPG can thus bring large benefits to both human health and the climate by reducing greenhouse gas emissions as well as black carbon (Floess and others 2023) (box 2.1). The avoided emissions of methane, black carbon, carbon monoxide and other climate forcing pollutants released during the inefficient combustion of biomass (or other solid fuels) in traditional stoves is higher than the additional emissions that may result from using a mix of LPG and electricity, even after considering the total energy value chain from production to use. This would be true even without accounting for the avoided black carbon emissions and the impact of the use of biomass on forests (IEA 2022a).

Alternative clean fuels such as biogas could facilitate transitions to clean fuels in rural areas while mitigating the impact of other sources of climate pollutants such as agricultural waste. For example, the West and Central Africa Alliance for Biodigester Promotion was established to strengthen deployment of biodigesters across eight countries, building on the experience of the Africa Biogas Partnership Program. In 2021, across selected countries in Sub-Saharan Africa, household biodigester adoption increased to more than 27 000 systems—a 10 percent increase from 2020 (SNV 2022).

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38 Black carbon is one of the most potent short-lived climate pollutants. It absorbs sunlight and heats the atmosphere. It has also been associated with cardiovascular damage and premature mortality.

### Box 2.1 • Clean household energy as a key climate change mitigation strategy

Transitioning from biomass to LPG and electricity for household energy is a net win for the climate, even after considering the entire energy life-cycle (Floess and others 2023). The analysis was conducted in 77 countries where at least 1 million people use polluting solid fuels and/or kerosene for cooking. Compared with a “business as usual” scenario, transitioning to all LPG, a mix of LPG and electricity, or all electricity reduced emissions of greenhouse gases by 17 percent, 31 percent, and 47 percent, respectively, and eliminated nearly all black carbon emissions from household cooking. The clean cooking scenarios yielded an average 5 mK reduction in global temperature by 2040 and a 6 Mt (99 percent) decrease in annual emissions of PM<sub>2.5</sub> by 2040.

Another analysis found similar results, showing that transitions to universal access to clean cooking by 2030 while leading to a slight increase in CO<sub>2</sub> emissions, overall led to net benefits for climate. Due to the avoided methane and nitrous oxide emissions from traditional biomass use, this analysis estimated that such a transition would result in a savings of 870 Mt CO<sub>2</sub>-equivalents (IEA 2022a).

Such analyses add to the evidence base on the potential for clean household energy solutions to contribute significantly to climate change mitigation. Findings on the costs and potential impacts of efforts to promote clean household energy can be used not only to increase awareness and commitment to achieving clean household energy transitions but also to drive increased investment.

The mounting evidence on the climate, health, and social co-benefits of clean household energy transitions highlights the importance of including commitments to wider access in Nationally Determined Contributions as a key strategy for slowing climate change and advancing toward the goal of net-zero emissions by 2050.

## KEEPING PACE WITH URBANIZATION

While the narrowing of the urban-rural disparity in access to clean cooking seen in most regions is encouraging,<sup>39</sup> urban areas’ projected stalled progress in the next two years is important to note. Historically, households in rural areas tend to rely on solid fuels such as charcoal and biomass because of their cheaper cost, their availability, and the relative inaccessibility of cleaner alternatives. On the other hand, urban areas often have infrastructure in place, such as paved roads and electricity grids, that can facilitate transportation and distribution of cleaner energy fuels and appliances. However, with the rapid pace of urban population growth in many parts of the world, supplying clean energy services is a looming challenge for cities, particularly in slums and informal settlements that are often characterized by poverty and concentrated deprivation (UN Habitat 2022). To avoid such an unhealthy transition, recommendations are needed for policies to deal effectively with intra-urban inequities and the constraints of the urban poor in accessing clean fuels and technologies. Such policy insights can then inform governments and other stakeholders on how best to invest in clean cooking access in these impoverished areas so that poor and vulnerable populations are not forgotten.

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39 The gap is narrowing in all regions except Sub-Saharan Africa, where it is increasing sharply.

## ENSURING CLEAN COOKING AS PART OF BROADER ENERGY PLANNING

Universalizing access to clean cooking will require the inclusion of clean cooking within broader energy planning efforts. Integrated energy planning is a promising approach that takes a holistic look at a country's energy system when planning for household and institutional access to electricity and clean cooking (SEforALL 2023). A well-crafted integrated energy plan can unlock actionable market intelligence for the private sector, policy makers, and funders by identifying priority geographic areas for expanding energy access and the least-cost technology to be deployed. Having such data maximizes efficiency in building infrastructure to provide services where they are most needed. The new data-driven Nigeria Integrated Energy Planning Tool, developed under this framework, is powered by extensive geospatial modeling and layers of data. Covering electrification, clean cooking, and productive uses of electricity, it provides actionable intelligence for the government, donors, investors, and private sector stakeholders to plan and deliver the least-cost access to electricity and clean cooking (SEforALL 2021).

## BUILDING COMMITMENTS FOR ACTION THROUGH NATIONALLY DETERMINED CONTRIBUTIONS AND ENERGY COMPACTS

Nationally Determined Contributions (NDCs) under the Paris Agreement on climate change and national clean cooking strategies and commitments, including energy compacts, can serve as opportunities or vehicles to pair political and financial commitments for scaling up action on clean cooking. As of October 2021, 67 countries included clean cooking- and other household energy-related goals in their NDCs (Clean Cooking Alliance 2021). Energy compacts have been mobilized since the United Nations (UN) High-Level Dialogue on Energy in September 2021 as a policy instrument to accelerate actions on clean cooking and other energy goals.

Ethiopia, Honduras, Kenya, Madagascar, Malawi, Nepal, Nigeria, Rwanda, Sierra Leone, and Zambia have all pledged in their energy compacts to accelerate access to clean cooking through 2030 and beyond. Not only low- and middle-income countries are committed. Netherlands and the United Arab Emirates have also pledged in their compacts to support clean cooking efforts (United Nations 2023). The Netherlands has recognized that clean cooking is a key solution to reducing carbon emissions and pledged its support for increased action to achieve universal access through multi-stakeholder partnerships, innovative business models, and financing strategies such as carbon credit markets to provide affordable clean cooking options to millions of the world's poorest and most vulnerable (United Nations 2023).

However, while the commitments are notable, most of the access targets specified in these compacts are below what would be required to achieve the SDG 7.1.2 target of universal access to clean cooking by 2030 (IEA 2022a). Nonetheless, countries pairing political and financial commitments to clean cooking have been able to show significant progress in the short term. This includes Kenya, which has been notably active in its political commitments and social enterprise efforts (box 2.2).

Other non-state actors, such as companies, regional and local governments, and nongovernmental organizations, have also joined in the commitment to accelerate access to clean cooking. For example, the Clean Cooking Alliance has launched a multilateral energy compact that aims to catalyze commitment and investment for clean cooking; the compact has been endorsed by more than 60 governments and organizations around the world (Clean Cooking Alliance 2023; United Nations 2023).

If realized, national targets to accelerate access to clean cooking, as spelled out in NDCs and energy compacts, have the potential to improve human health, livelihoods, the climate, and the natural environment at large. Promoting the

### Box 2.2 • Kenya: Championing clean cooking

Over the last decade, Kenya's rate of access to clean cooking technologies rose by 15 percentage points, from 9 percent in 2012 to 24 percent in 2021. The increase translates into close to 10 million people gaining access. Kenya has been active on the clean cooking front at all levels, from much needed political support by the government and political leaders—including First Lady Rachel Ruto (Nation 2022)—to encouraging private enterprises that bring high-quality, energy-efficient, and affordable stoves and fuels to the most vulnerable and underserved populations (MECS 2021).

Although there have been setbacks in access to clean cooking as a result of the COVID-19 pandemic, numerous countries, Kenya among them, remain committed to accelerating action on clean cooking, as recently evidenced by their commitments in energy compacts (United Nations 2023).

Kenya has pledged in its energy compact to universalize household use of clean cooking technologies and fuels by 2028 through actions such as communication strategies, targeted subsidies, and consumer financing. Kenya's clean cooking commitment goes beyond just universal access for households. The country additionally pledges in the compact to transition all public institutions from the use of biomass cooking fuels by 2025. All micro, small, and medium-sized enterprises in the cooking and hospitality sectors will similarly convert to clean cooking solutions by 2028. Kenya has set a budget of USD 605 815 000 to achieve these goals.

Kenya's target to reach universal clean cooking by 2028 aligns with the country's announcement to develop a National eCooking Strategy, one of the first electric cooking strategies of its kind in Africa. The strategy will encourage the use of electric cooking appliances through media campaigns, cooking classes, and demonstrations. Kenya Power and Lighting Company has also begun to explore on-bill repayment for electric cooking devices to encourage households to switch (IEA 2022a).

Kenya's ambitious compact, political engagement, and eCooking strategy set an excellent example of a holistic approach to scaling up clean cooking to advance national agendas in health, development, and the environment.

use of a range of cleaner cooking fuel options such as electricity, LPG, ethanol, and biogas should thus be upheld as an important implementable action for countries to use to advance development outcomes, preserve nature, and mitigate and adapt to the effects of climate change.

## TACKLING AFFORDABILITY TO ENHANCE THE ADEQUACY OF POLICIES

Subsidies can help bridge the affordability gap by reducing the upfront and recurring costs of clean cooking systems; they have been instrumental in expanding LPG use in multiple Latin American countries (MECS 2020) (box 2.3). Through the Indian government's Pradhan Mantri Ujjwala Yojana initiative, launched in 2016, hundreds of millions of dollars have been allocated to expand LPG coverage to over 50 million low-income households through targeted LPG subsidies, accompanied by the establishment of thousands of new LPG distributors to meet growth in demand (WHO 2018; Singh, Pachauri, and Zerriffi 2017; Ministry of Petroleum and Natural Gas 2016). China's coal-to-electricity program, in which a ban on household coal use was implemented alongside subsidies for new technologies, demonstrates policy mechanisms that jointly consider clean fuel adoption and disincentives for the use of polluting fuel (Barrington-Leigh and others 2019). The latter is an essential component of the clean energy transition process that is often overlooked, but equally critical to reduce air pollution and reap benefits to health and the climate.

### Box 2.3 • Affordability: Learning from the Latin American clean cooking transition

Over the last three decades, low- and middle-income countries in the Americas have made substantial progress in scaling up clean cooking. Almost 90 percent of the population in the Americas now rely chiefly on clean fuels and technologies for cooking. Households in urban areas report almost exclusive use, with 97 percent of urban households mainly using clean fuels and technologies for cooking (97 percent of the urban population and 74 percent of the rural population). As a region and with some 75 million in mainly 10 countries lacking access to clean cooking, the Americas is on its way to a complete regional transition to clean cooking.

Understanding the factors that have enabled the successful transition of a majority of the population over the past 30 years can provide valuable lessons for other low- and middle-income countries working toward the elimination of polluting cooking practices.

Affordability of both stoves and recurring fuels costs is one of the greatest barriers for low-income households considering clean cooking solutions. Households often face hard choices when it comes to spending limited resources and, in many cases, clean cooking is often not prioritized. However, governments can take steps to tackle the affordability barrier. In the case of Latin America, the most common step has been end-user subsidies.

End-user subsidies for cooking stoves and fuels have been used in many Latin American countries since the 1970s, with variations in price point and delivery mechanism. Much can be learned from the historical record.

Bolivia, Ecuador, and El Salvador each has a rural population of about 30 percent. All three countries have provided substantial subsidies for LPG fuel for cooking. The subsidies cover 60–95 percent of the cost of LPG (Gould and others 2018; OLADE 2013).

In El Salvador, a 65 percent universal LPG subsidy was put in place in 1974; it was replaced in 2011 with a targeted subsidy of one 25-pound LPG cylinder per month per family, covering almost 70 percent of the population (Calvo-Gonzalez, Cunha, and Trezzi 2015). Access to clean fuels reached 93 percent in 2021, much higher than neighboring Central American countries without an LPG subsidy: Guatemala, 48 percent; Honduras, 50 percent; Nicaragua, 57 percent; and Mexico, 85 percent.

Largely as a result of subsidy policies, 95 percent of Ecuador's population uses LPG for cooking; Bolivia's figure is 82 percent. In comparison, Peru and Paraguay, neighboring countries with higher GDP per capita and similar or higher rates of urbanization, stand at 76 percent and 66 percent, respectively.

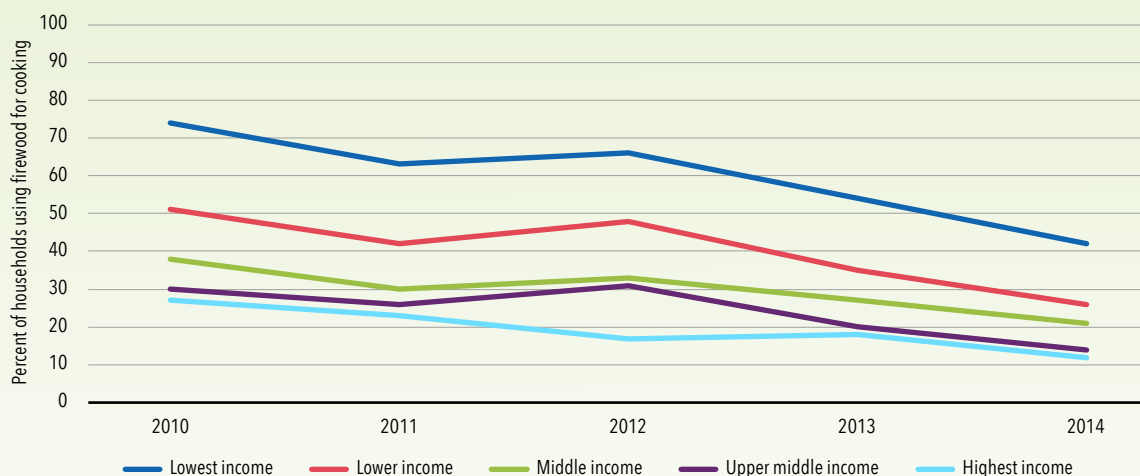
Implementing the subsidies was not without challenges. Each country faced different implementation issues. In Bolivia, for example, the lack of infrastructure to maintain a reliable distribution of LPG to remote and poorly connected areas presented problems. In El Salvador, the 2011 shift of the subsidy from universal to targeted had an almost immediate impact on fuel-use patterns, with many households reverting back to polluting cooking stoves and fuels (figure B.2.3.1). In light of this, the government quickly adapted the policy to be more targeted by income group, resulting in an immediate shift back to LPG usage among the poorest populations. Likewise, in Ecuador, because of the high costs of imported LPG, the government invested in a program to substitute local renewable electricity for LPG in 2014 (Gould and others 2018). Massive protests made it impossible to remove the LPG subsidy, however, and most households still cook with LPG.

These countries provide lessons on the use of end-user subsidies to support the transition to clean cooking:

- In some countries, the sustained practice of clean cooking is highly dependent on subsidies and very sensitive to changes in policy and price.

- Urbanization is a driver of change, but the urban-rural gap in access to clean fuels for cooking is also sensitive to fuel subsidy policies.
- Low-income countries may need sustained and focused development aid to overcome infrastructure and resource constraints, particularly in the most remote areas.
- Transitioning from LPG to electricity is complex, requiring investment in infrastructure and changes in cooking practices.

**Figure B.2.3.1 • Use of firewood in rural areas of El Salvador by wealth**



Source: Encuesta de Hogares de Propósitos Múltiples (EHPM 2014).

Scaling up investment in clean cooking is an investment in social goods. The timing is more critical than ever for policy makers and funders to redouble efforts to unlock finances for clean cooking. It is also important to understand lessons learned from past policies, such as those highlighted in the World Bank's Regulatory Indicators for Sustainable Development report (ESMAP 2022) and WHO's Household Energy Policy Repository (WHO 2021c).<sup>40</sup>

40 The Regulatory Indicators for Sustainable Energy (RISE) assesses countries' national policies and regulatory frameworks for sustainable energy according to a set of standard indicators. These resources can serve as a useful knowledge base to draw valuable lessons and spark discussions on what policy mechanisms are most likely to be successful and which might be implemented at scale. WHO's Clean Household Energy Policy Repository compiles national, regional, and local policies on clean household energy that include financial measures (such as taxes, subsidies, or voucher programs), regulatory instruments (such as limits or bans on specific fuels or technologies), trade policies, direct investments, codes and standards, and information campaigns.



## **PATH FOR PROGRESS FOR SCALING UP CLEAN COOKING: URGENT ACTION REQUIRED FOR UNIVERSAL ACCESS BY 2030**

There are encouraging signs that efforts to scale up clean cooking access are moving forward in some places. Transitioning to clean cooking is accelerating in certain countries—China, Ghana, Kenya, and India chief among them—that have made good progress in recent years through increased political support and advocacy, matched by adequate financial commitments and actions on the ground.

While there has been some progress over the past two decades in expanding access to clean fuels and technologies for cooking, there is an urgent need to further scale up ambition and action to achieve universal access to clean cooking by 2030. Enhanced innovation in delivery mechanisms paired with large-scale public investment to crowd in private investment is needed to lower the cost of clean cooking needed to accelerate progress. Furthermore, clean cooking needs to remain high on global political agendas. With the upcoming voluntary review of SDG 7 including clean cooking at the High-Level Political Forum as well as the SDG Summit and Climate Ambition Summit in September 2023, global leaders and governments will have the opportunity to demonstrate their commitments to clean cooking to achieve various health, climate and other cross-cutting goals.

## **Outlook**

### **1.9 BILLION PEOPLE WILL STILL LACK CLEAN COOKING IN 2030**

Regardless of whether one considers the current rate of progress in energy access, current policies, or pledged policies, the world is far off pace to achieve the universal target to clean cooking by 2030. Based on current trends, WHO estimates that 1.9 billion people will still lack access to clean cooking by 2030. The International Energy Agency's (IEA) Stated Policies Scenario yields similar figures, even after accounting for the positive impacts of policies already in place (IEA 2022b).

Under IEA's Announced Pledges Scenario,<sup>41</sup> which assumes that all aspirational targets announced by governments are met in full and on time, the outlook is less grim but still off-track, with an estimated 0.7 billion people still relying on traditional stoves and fuels in 2030.

Given current trends, the pledge made at the UN's 2021 High-level Dialogue on Energy to ensure that an additional 1 billion people would gain access to clean cooking solutions by 2025 will not be reached.<sup>42</sup> The number of people with access to clean cooking will increase by only 510 million from 2021 to 2025. The expected access deficit is largely concentrated in Sub-Saharan Africa, where almost 60 percent of the population is projected to still lack access to clean cooking in 2030.

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41 IEA introduced the Announced Pledges Scenario in 2021. It aims to show to what extent the announced ambitions and targets, including the most recent ones, are on the path to deliver emissions reductions required to achieve net zero emissions by 2050 (IEA 2022b). Compared to the Stated Policies Scenario, it includes announcements on pledges and targets, regardless of whether these have been anchored in legislation or in Nationally Determined Contributions.

42 The pledge was made during the High-level Dialogue on Energy in 2021, as part of the Global Roadmap for Accelerated SDG7 Action in Support of the 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change (United Nations 2021).

## COVID-19 AND SOARING ENERGY PRICES THREATEN CLEAN COOKING ACCESS FOR MILLIONS

The IEA estimates that the combination of the COVID-19 pandemic and current soaring energy prices will put basic electricity out of reach for almost 75 million people (IEA 2022a). The same affordability issues are expected to have an even more dramatic impact on the clean cooking transition, with 100 million people who recently transitioned to clean cooking expected to revert to using traditional biomass due to affordability issues. Between 2019 and 2021, Eastern Asia and Latin America and the Caribbean were the only regions to sustain progress in access to clean cooking (ESMAP 2022).

The goal of achieving universal access to electricity and clean cooking will require a massive increase in governmental efforts to regain the momentum. Yet only 39 of the 128 countries currently lacking universal access to clean cooking have set clean cooking targets, and less than half of those aim to achieve universal access by 2030 (IEA 2022a). The current policy ambitions are therefore far from the targets of SDG 7. It is necessary to improve implementation and raise the level of ambition in many countries to bridge the gap between the current situation and the SDG 7 targets.

## CLEAN COOKING – AN IMPORTANT ELEMENT ON THE PATHWAY TO NET ZERO

Clean cooking is a potent way to fight climate change. The unsustainable harvesting of fuelwood and high-levels of emissions (particularly black carbon from inefficient household energy use) have detrimental effects on the climate, thus jeopardizing the future of humanity and the planet. Climate change is expected to cause approximately 250 000 additional deaths each year from 2030 to 2050 owing to malnutrition, malaria, diarrhea and heat stress alone (WHO 2021b).

The pathway to arresting the rise in the world's average temperature to +1.5 °C therefore requires immediate actions from the entire energy sector, and clean cooking can play an important role. Accounting for the emissions of the full energy lifecycle (i.e. both upstream and end-use emissions), shifting households entirely to LPG could curb short-lived climate pollutants emission almost entirely (Floess and others 2023). But for that to happen, under IEA's Net Zero Emissions by 2050 Scenario (IEA 2022b), the rate of improvement in access to clean cooking will have to rise dramatically from an annual increase of 1.7 percentage points between 2015 and 2019, to 2.7 percentage points, nearly double the current rate of progress. Looking at regional trends is critical, as access rates vary greatly. While low- and middle-income countries in Asia will have to improve their rate by 1.5 times, improvements in Sub-Saharan Africa will have to increase by a magnitude of 15 times (IEA 2022a).

## CREATING A VOICE FOR CLEAN COOKING IN THE COMMUNITY

The benefits of clean cooking need to be better understood. From policy makers to the stove user, understanding the benefits and advantages of clean cooking is an important element needed to drive a sustained transition to clean cooking. Various efforts are underway to strengthen and coordinate positive messages about the environmental, climate, and health benefits of clean cooking to a broad set of stakeholders. For example, in Bangladesh, messages regarding the health benefits of clean cooking were mainstreamed into cooking TV shows to better reach younger audiences (Clean Cooking Alliance 2023). Similar efforts are being used in Ghana to integrate the health and environmental impacts of traditional and clean cooking into the school curriculum. Enhanced messaging via social media and local advertising is used in Kenya and Nepal, among other places, to broaden the uptake of clean cooking solutions. Good communication about the benefits of clean cooking is an essential complement to any policy or program.

## **COSTING THE CLEAN COOKING TRANSITION**

According to the World Bank, the health costs alone from lack of clean cooking are estimated at USD 1.4 trillion per year (ESMAP 2020). Women are particularly affected, and their loss of productivity amounts to USD 0.8 trillion every year. When adding environmental costs, the price tag comes to USD 2.4 trillion a year, far greater than the cost of transitioning to universal modern energy cooking services (USD 148–156 billion annually over the next 10 years, for a total of USD 1.5 trillion). Greater efforts should be made to calculate with precision the negative externalities of failing to universalize access to clean cooking in terms of productive time lost, missed opportunities for schooling, and environmental damage. Given the direct effect of polluting fuels and technologies on climate change funding could be leveraged to fill at least part of the gap (UN DESA 2018).

## **NEED FOR ACTION FOR HEALTHIER LIVES AND ENVIRONMENT**

The benefits of clean cooking are far too high to delay any further. Billions of the world's people are suffering from the adverse health, environmental, and economic effects of polluting cooking practices. The humanity faces unprecedented challenges with triple planetary-crisis of pollution including household air pollution, biodiversity loss and climate change. Clean cooking has been proving an effective entry-point to tackle and help mitigate the impacts, from economic losses to deterioration of life on our planet. The cost will continue to mount unless political and financial commitments rise to meet the challenge. The moment to act is now.

# Methodological Notes

## DATA SOURCES

The WHO Household Energy Database contains nationally representative household survey data (WHO 2018). Regularly updated, it relies on several sources (table 2.1) and serves as the basis for all modelling efforts in this report. The database contains more than 1,500 surveys conducted in 171 countries (including high-income countries) between 1960 and 2022. A quarter of the surveys cover the years 2013 to 2018; 250 new surveys cover 2016 to 2022. Modelled estimates are provided only if there is underlying survey data on cooking fuels, so there are no estimates for Lebanon, Libya and Bulgaria.

Population data are from United Nations (2018).

**Table 2.1 • Overview of data sources for clean fuels and technology**

NAME	ENTITY	NUMBER OF COUNTRIES	DISTRIBUTION OF DATA SOURCES (IN PERCENT)	QUESTION
Census	National statistical agencies	108	18.4	What is the main source of cooking fuel in your household?
Demographic and Health Survey (DHS)	Funded by USAID; implemented by ICF International	81	17.2	What type of fuel does your household mainly use for cooking?
Living Standards Measurement Survey (LSMS), income expenditure surveys, and other national surveys	National statistical agencies, supported by the World Bank	26	3.00	Which is the main source of energy for cooking?
Multiple Indicator Cluster Surveys (MICS)	UNICEF	80	10.90	What type of fuel does your household mainly use for cooking?
Study on Global AGEing and Adult Health (SAGE)	WHO	6	0.40	NA
World Health Survey	WHO	50	3.80	NA
National surveys		107	35.80	NA
Other		79	10.30	NA

## MODEL

As household surveys are conducted irregularly and reported heterogeneously, the WHO Global Household Energy Model (developed in collaboration with the University of Glasgow) is used to estimate trends in household use of six fuel types:

- unprocessed biomass (e.g., wood)
- charcoal
- coal
- kerosene
- gaseous fuels (e.g., LPG)
- electricity

Trends in the proportion of the population using each fuel type are estimated using a Bayesian hierarchical model, with urban and rural disaggregation, drawing on country survey data. Smooth time functions were the only covariate. Estimates for total polluting fuel use (unprocessed biomass, charcoal, coal, and kerosene) and total clean fuel use (gaseous fuels, electricity, and an aggregation of other clean fuels, such as alcohol) are produced by aggregating estimates of relevant fuel types. Estimates produced by the model automatically respect the constraint that the total fuel use equals 100 percent.

GHEM is implemented using the R programming language and the NIMBLE software package for Bayesian modelling with Markov chain Monte Carlo (MCMC). Summaries can be obtained to provide both point estimates (e.g., means) and measures of uncertainty (e.g., 95 percent credible and 95 percent prediction intervals). The GHEM is applied to the WHO household energy database to produce a comprehensive set of estimates, together with associated measures of uncertainty, of the use of four specific polluting fuels and two specific clean fuels for cooking, by country, for each year from 1990 to 2019. Further details on the modeling methodology and validation can be found in Stoner and others (2020), and more detailed analysis of individual fuel use can be found in Stoner and others (2021).

Only surveys with less than 15 percent of the population reporting “missing,” “no cooking,” and “other fuels” were included in the analysis. Surveys were also discarded if the sum of all mutually exclusive categories reported was not within 98–102 percent. Fuel use values were uniformly scaled (divided) by the sum of all mutually exclusive categories, excluding “missing,” “no cooking,” and “other fuels.” Countries classified by the World Bank as high-income (58 countries) in the 2021 fiscal year were assumed to have transitioned to clean household energy. They are therefore reported as having >95 percent access to clean fuel and technologies; no fuel-specific estimates were reported for high-income countries. In addition, no estimates were reported for low- and middle-income countries without data suitable for modeling (Bulgaria, Lebanon, and Libya). Modeled specific-fuel estimates were reported for 130 low- and middle-income countries plus 3 countries with no World Bank income classification (Venezuela, Niue and Cook Islands); estimates of overall clean fuel use were reported for 191 countries.

## UNCERTAINTY INTERVALS

Many of the point estimates we provide here are accompanied by 95 percent uncertainty intervals, which imply a 95 percent chance that the true value lies within the given range. Small annual changes in the point estimate may be statistical noise arising from either the modeling process or survey variability and may therefore not reflect a real variation in the numbers relying on different fuels between years. The uncertainty intervals should therefore be considered when assessing changes in the access rate, or in the use of specific fuels, between years.

Moreover, for some countries a lack of recent survey data (e.g., in the last 10 years) naturally leads to very wide uncertainty intervals associated with estimates for 2021 and preceding years. For countries with very wide uncertainty intervals, point estimates should be treated with some caution.

## GLOBAL AND REGIONAL AGGREGATIONS

Population data from the United Nations Population Division (United Nations 2018) were used to derive the population-weighted regional and global aggregates. Low- and middle-income countries without data were excluded from all aggregate calculations; high-income countries were excluded from aggregate calculation for specific fuels.

The aggregation methods used ensure that uncertainty in the percentage of people and absolute number of people using different fuels for cooking in individual countries propagate into the uncertainty intervals accompanying global and regional estimates.

## ANNUALIZED GROWTH RATES

The annualized increase in the access rate is calculated as the difference between the access rate in year 2 and that in year 1, divided by the number of years to annualize the value:

$$(\text{Access Rate Year 2} - \text{Access Rate Year 1}) / (\text{Year 2} - \text{Year 1})$$

This approach takes population growth into account by working with the final national access rate.

## PROJECTIONS

Projected access rates, access deficits, and fuel use can be estimated using the GHEM, where uncertainty increases the further into the future estimates are calculated, reflecting how country trends may shift based on how unsettled they were during the data period.

Projections in this chapter are hypothetical scenarios in which no new policies or interventions (positive or otherwise) take place. As such, they are useful as baseline scenarios for comparing the effect of interventions. The scenarios are calculated by extrapolating current trends into the future.

The estimated year each country will achieve 95 percent access to clean fuels and technologies is taken from these projections.



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